

THE GLACIAL EPOCHS,

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(*Read before the American Philosophical Society, March 3, 17, and April 3, 1876.*)

The Geologists speak of the Glacial Epoch, with a ready confidence that implies they consider it an admitted doctrine of their science; and they mean by "the glacial age," one of continental ice sheets. Glacialists have written large volumes on the subject, and its literature is swelling into a library. Agassiz, born and educated among the Alps, studied their glaciers and their effects, and traveling thence, applied his theories to other parts of the world. He was very sincere in his convictions, and complained that so few of his colleagues accepted his views; but in the confidence that he held a great truth he was willing to abide the coming of the time he foresaw, when Geologists would generally accept his theory. That time seemed to have arrived before he died, with some distinguished exceptions.

Those who have made Geological Surveys of England and Scotland, and parts of the Continent of Europe, either as conductors of public Surveys, or as Professors in colleges, or teachers through the press, find the ready explanation of what they see, in the doings of the great Glacial Epoch, when the supposed Northern ice-sheet filled the Arctic Ocean, the British and Irish Seas, and covered Northern Europe continuously over land, rivers, seas and mountains, to shed its icebergs far out into the Atlantic. And so too in this broad country, the Geologists who have made our public Surveys, who teach in our colleges, or publish, have generally read the rocks and drifts in the same way, in making explorations that have extended over the length and breadth of this continent.

Geologists, as other scientists, must follow the truth as the facts of nature compel them. Truth's compulsion is as inexorable as the pressure of the gigantic ice-sheets, these glacialists suppose, bore down from the pole. But they, as others, must often review their facts before they accept a theory as conclusive, and make themselves sure that they have not, by an engrossing attention to limited facts, overlooked others which should have influenced their theorizations.

They teach that the Glacial Epoch has occurred twice at least, since the rocks were laid in the strata as we see them; long after the coal measures were formed; of which the evidence is to be found upon the surface of the rocks as they now exist, and in the clays, and drifts, and boulders now spread over those rocks. Geologically speaking, these phenomena are of recent date, although before the Niagara began to cut the channel we now see. The astronomical cause assigned for them gives them a periodicity of about twenty-one, to twenty-two thousand years, and our northern hemisphere the respite of the half of such period, before it shall again be ground into paste.

We have the deepest interest, as a truth of science, to know what have been the causes that have deeply modified the surface of the world we inhabit ; and a yet deeper interest in knowing what shall befall that part of the northern hemisphere now occupied by the most intelligent and civilized portion of mankind, with their wealth, cities, cultivation, and works of transportation and travel ; for if the theory be true all these will be ground into the comminution of the boulder clay that flows from beneath the glacier of the Alps ! When men pay for real estate they exact an extreme scientific care that they get a fee simple title forever, -Why be so anxious, if all is to be razed, leaving them an interval of but a term of years. Yet more ; we cannot but sympathize with a posterity destined so to perish ; and with the shock to the faith of those who believe in a Creator, capable, and willing to conserve His creation.

Let us then see what this supposed continental ice-sheet is. Listen then to the very words of Agassiz, author of the theory : "It is a sheet of snow ten or fifteen thousand feet in thickness, extending all over the northern and southern portions of the globe ; and must necessarily lead, in the end, in the formation of a northern and southern cap of ice, moving to the equator." Speaking of the northern, Agassiz further says : "As to the southward movement of an immense field of ice, extending over the whole north, it seems inevitable, the moment we admit that snow may accumulate round the pole in such quantities as to initiate a pressure radiating in every direction," "alternately thawing and freezing, it must, like water, *find its level* at last." "In the State of Maine, I have followed, compass in hand, the same set of furrows, running from north to south in one unvarying line over a surface of one hundred and thirty miles from the Katahdin Iron Range to the shore. These furrows follow all the inequalities of the country, ascending ranges of hills varying from twelve to fifteen hundred feet in height, and descending into the intervening valleys two or three hundred feet above the sea, or sometimes even on a level with it." (A Journal to Brazil, 403, 402.) These all are words of Agassiz, with no word of apprehension or sympathy for his fellow beings, for whose welfare the noble labors of his life were devoted.

Agassiz gives further explanation of his views on the "Ice period in America," in the *Atlantic Monthly* for July, 1864. The ice moved over the continent as one continuous sheet overriding nearly all the inequalities of the surface, p. 88. Fragments of rocks from Lake Superior are found in New England, and northern rocks on the prairies of Illinois and Iowa, down to the fortieth degree of latitude. Polished rocks and straight scratches may be seen for hundreds and hundreds of miles. The slopes of the Allegheny range are glacier-worn to the very top, with the exception of a few points. Mount Washington is over six thousand feet high and wears glacier marks to near its summit. Here the thickness of the sheet could not have been less than six thousand feet. If much lower than that the ice passed over the mountains. He asks us to imagine the climate of Greenland brought down to the fortieth degree of latitude, with ice thousands of feet thicker

than it is there at present. Norway, Sweden, Scotland, England, Ireland, were so covered, p. 92. This, it is true, was long ago; yet late cave explorations are supposed to indicate, that the latest glacial epoch was since man inhabited the earth.

Professor Winchell, adopting the glacial theory, states its causes and effects. He rather delights to make science sensational and astonishing: "The high northern latitudes experience an *unwonted uplift*. Arctic lands raise high their dripping heads above the temperate waters of the polar zone. The climate of the whole northern hemisphere feels the change: No moving currents can now bear torrid warmth to the frozen sea, and return the colder waters to the equatorial zone." "The snows of many winters are gathered on the slopes of Northern America." "Glaciers brood over all the land." "The marks of this stupendous glacier are yet visible." "The northern limit was chained by eternal frost to its rocky bed. The southern only was free to move, and the whole expansion would be developed along the southern border." (Sketches of Creation, 214.) "From season to season, and from year to year, the mighty mass marched irresistibly forward, mowing down the forests, crushing tree-trunks, or burying them with the rubbish of the rocks, from ten to sixty feet below the surface." "The great glacier moves onward." "It bridged Niagara River; it bridged Long Island Sound, and bathed itself in mild waters of the ocean beyond," p. 218, 219. "It made a *tabula rasa*." River channels were filled up; "In Ohio and Indiana these buried river-beds are of frequent occurrence. The ancient gorge of the Niagara River was filled by the obliterating agency of this continental glacier." "It wiped out the trifling furrow, * * making it necessary for the river to begin anew its work," 219, 220. It bore rocks southward twenty, fifty, and even five hundred miles. "These fragments have been transported over lakes, sounds and seas." The glacial agency is not recognized south of the Ohio River, 220, 221. The south was spared; nay, greatly favored; for except the chain of mountains, the material ploughed up by the ice was carried by the waters to make the Cretaceous seaboard, the Gulf states and the many more of the Mississippi, and Missouri valleys.

This reign of ice came after the close of the carboniferous age, and after the land was upraised and dry, and vegetable and animal life existed on it as now, except that man was not yet here. Winchell is so speaking (219, 213), and then says, "Next in the order of vicissitudes was a grand continental subsidence. Vast areas of Northern America, that had been raised to the altitude of perpetual snow, were gradually lowered to the ocean's level. Again the interchange of equatorial and polar temperatures was affected by the moving sea-currents, and the climate of summer smiled over the desolate empire of frost," 222. "By degrees Wisconsin, Michigan, New York, Ohio and other Northern States disappeared beneath the waves," p. 228. "It seemed like a failure of the plan of creation. The land gained by *unnumbered throes* of the continent was lost. The higher summits only held their heads above the level of the careering

waves. Deposits bearing the marks of oceanic action reach to an elevation of six thousand feet on *Mount Washington*, two thousand or more on the Green Mountains, and *three thousand* on *Monadnock*. But this deep submergence was not of long continuance. Slowly the continent rose again from its deep sea burial," 229. Thus the continent here, as we shall see in Europe, seems to rise and fall thousands of feet at the bidding of theorists.

The Ohio Geological Report of 1873, written by Dr. Newbury, is equally threatening; 1 vol. 85: "The period immediately following the Tertiary age in geological history, but separated from it by we know not how many thousands of years, presents us with a complete change in the physical condition not only of our own continent, but apparently of the whole northern hemisphere; a change not exceeded by that which takes place upon our surface in the alternations of season from mid-summer to mid-winter. We have abundant evidence that during what is called the drift period the climate of our continent had changed from the all pervading warmth of the Tertiary to an all pervading arctic cold. While in the former age the climate of our Southern States was carried to Greenland, in the latter the *present climate of Greenland was brought as far south as the Ohio*. The continent of Greenland is now nearly buried under snow and ice." "Precisely such must have been the condition of much of the North American Continent during the glacial period, for we find evidence that glaciers covered the greater part of the surface down to the latitude of 38 or 40 degrees." The smoothed and grooved rocks are covered with the glacial drift deposits; and upon and mingled with it, is the Erie clay; deposited from suspension in water and stratified; doubtless from basins where had been the retreating glaciers, p. 86.

If geologists did not produce so many restorations of the past, full of wonderful instruction, we would be apt to say that surely the imagination had large operation in making such confident explanations of the past doings of Nature upon this globe. Grand, sublime, were and are her operations; but one cannot help thinking if they could be seen that their progression was slow and orderly, without extreme vicissitudes, and as harmless as we now see them. There was ample time for the work; and Geologists readily allow any amount needful for observed effects, counting a thousand years as a day. The sedimentary rocks show that the process was generally a quiet one, the more modern with fewest faults; and certainly nothing could have been more carefully done, than the manner of the growth and storing away of the coal and oil, under their rocky coverings for the use of the human beings that were to occupy the world. Excepting the ventilating volcanoes, and the mountain-heaving earthquakes, the elevations and depressions of the earth have been at the rate of but a few feet in a century, so that it can hardly be soberly said that the land was gained by "un-numbered throes." Nay the probability seems to be that the concurring operation of the sinking of the sea beds and the raising up of the mountains, the one balancing the other, were then as now, only to be gauged by the lapse of the centuries, so quiet and imperceptible were they. Geology

has no chronology of years, but only of the order of its own successions, and the preparations, in the "beginning" of this earth, for man, there is every evidence was very long, and not violent.

James Geikie writes in more measured and careful language than any of those who have lately written on the Glacial theory; and he may, therefore, be allowed to be its reliable expositor. Writing "The Great Ice Age," he says, "We must believe that all the hills and valleys were once swathed in snow and ice; that the whole of Scotland was at some distant date buried underneath one immense *mer de glace*, through which peered only the higher mountain-tops. This is no vague hypothesis, or speculation founded on uncertain data, no mere conjecture which the light of future discoveries may explode. The evidence is so clear and so overwhelmingly convincing that we cannot resist the inevitable conclusion." p. 82. "Now the scratches may be traced from the islands and the coast-line up to the elevation of at least 3,500 feet; so that ice must have covered the country to that height at least." 83. Agassiz added one-third to the height scored, that the ice-sheet might have a back pressure to pass it over the elevations. "Such changes happened not once only, *but again and again*," says Geikie, 200.

Of North America, Geikie says, It is no exaggeration to say, that the whole surface, "from the shores of the Arctic Ocean to the latitude of New York (City), and from the Pacific to the Atlantic, has been scaped, scraped, furrowed and scoured by the action of ice." 411.

And the conclusion of Geikie's Great Ice Age is this. "Upward of 200,000 years ago the Earth, as we *know from the calculations of astronomers*, was so placed in regard to the Sun that a series of physical changes was induced, which eventually resulted in conferring upon our atmosphere a most intensely severe climate. *All Northern Europe and North America* disappeared beneath a thick crust of ice and snow, and the glaciers of such regions as Switzerland assumed gigantic proportions. The great sheet of land-ice leveled up the valleys of Britain and stretched across our mountains and hills down to low latitudes in England." And so it is said as to the north of Europe. "Ere long this wonderful scene passed away. Gradually the snow and ice melted; the arctic mammalia disappeared; the climate grew milder, until something like perpetual summer reigned in Britain. Then it was that the hippopotamus wallowed in our rivers, and the elephant crashed our forests; then, too, the lion, the tiger, and hyena became denizens of the English caves." Then after a "long time" it grew cold; these tropical animals disappeared, and the arctic beasts came back; but the climate became so severe that even these "migrated southward, *until all life* deserted Britain, and snow and ice were left in undisputed possession. *Once more* the confluent glaciers overflowed the land, and desolation and sterility were everywhere." "We cannot say how often such alternations of cold and mild periods were repeated." "A similar succession of changes transpired in North America." The palæolithic man was here in the inter-glacial period, and frozen out! 534, &c.

In Scotland "the direction of the scratches, ruts, and grooves upon the rock head, usually *coincides with the trend of the valley* in which the till occurs." Geikie's Ice Age, 21. "In the Northern Highland * * they keep parallel to the trend of the great glens; and in the Southern Uplands, likewise, they follow all the windings of the chief dales and 'hopes.'" p. 80. A hope is a sloping plane between ridges of mountains. Let us remember these local indications.

And James Geikie asks, "What do we learn from the erratics?" the far-traveled blocks over the whole face of the country. "The highland boulders on the Pentlands and Lammermuirs, for example, after crossing Strathallan or Strathearn, traversed either the Campsie or Ochil Hills, and passed athwart the broad vale of the Forth before they finished their journey. By what agent were they transported? The answer is by a colossal glacier." p. 223-4. "It is a fact that most, if not all, the *erratics* have traveled in directions that coincide with the *trend of the rock-striae*." "The erratics lying loose upon the ground have moved in the identical direction, followed by the till of the same regions; a direction which it need hardly be said coincides with that of the underlying rock-striations. Indeed, when the *till* is carefully searched it not infrequently *yields fragments of the same rocks* as those of which the erratics lying *loose at the surface* are composed." 224-5. Mark how coincident with the topography.

He further proceeds to say, that after the great glacial deposits of Scotland, "the country at length became submerged to a depth in the south-east and west midland district of probably as much as 1,100 or 1,280 feet." 353, 255. "The river deposits of the lowlands were *now partially re-assorted*, or top-dressed, as it were, by the action of the sea. As the submergence approached its climax the temperature became colder; *ice-rafts flouted about*, and *dropped boulders over the sea-bottom*. These are now found floating on the slopes of the reassorted gravels, and enclosed in stratified clays, the character of the shells in which prove the climate to have been severe." 353.

Mr. J. Geikie finds in England, Wales and Ireland the like evidence of glaciation, of depression of the land and inflow of the sea, and the elevation again of the land; but no true *till* has been found in east Anglia. 371. "The striae upon the rocks, and the direction in which the till has traveled, mark out clearly the path taken by the great sheet of ice which wrapped up Ireland even as it enveloped Scotland." 373.

Scandinavia, Northern Europe generally, Switzerland, the Vosges, Black Forest, and Pyrenees, bear evidence of former Arctic conditions. "Even as far south as latitude 37°, the former existence of glaciers in the Sierra Nevada has been proved;" * * "and so on with most, or perhaps all, the hillier regions of Europe, great snow fields existed where now there are none," or but "insignificant successors." 379. And the like account is given on the testimony of travelers of Caucasus, Atlas, Lebanon, the Himalaya, and mountains in the north of China and in North America. "The direction of the glaciation in the extreme north of Scandinavia, the

peninsula of Kola, and Northeastern Finland demonstrates that the great *Mer de glace radiated outwards from the high grounds* of Norway and Sweden, flowing *north and northeast* into the Arctic Ocean and east into the White Sea, and thus clearly proving that Northern Europe was *not overflowed by a vast ice-cap creeping* outward from the North Pole, as some geologists have supposed." 382. These are Geikie's words; and here he is at issue with James Croll and Agassiz.

Geikie proceeds: "After that boulder-clay had been laid down, dry land appeared in Scotland and the north of England; and at a later date, a movement of subsidence ensued which resulted in drowning Wales to a depth probably of not less than two thousand feet." "All we know is that Scotland, Wales, and the north of England were largely submerged." Geikie, 479. The south and southeast of England was not submerged, and that portion only contained paleolithic instruments; but the neolithic occur everywhere in and throughout the British Islands; 480; and here were no traces of glaciation; 479; the line of division being the middle of England; 484. The islands and continent became connected; 485.

He says: "It is remarkable, that nowhere in the great plains of Siberia do any traces of glacial action appear to have been observed." *Ib.* 495. "Consequently we find the great river deposits with their mammalian remains, which tell of a milder climate than now obtains in those high latitudes, still lying undisturbed at the surface." 496.

In the regions of Alaska, west of the Rocky Mountains we have, says James Geikie, "a continuation of the same physical conditions that characterize the more northern latitudes of Asia, namely, great plains intersected by large rivers. Along the banks of these rivers, north of Mount St. Elias, numerous mammalian remains, especially the mammoth, have been detected." "But in the northern latitudes, east of the Rocky Mountains, no such mammalian remains have been detected." "They are rare also or altogether wanting in Canada." "Nevertheless, proofs are not wanting of a former mild condition of things having prevailed within comparatively recent times in the far north of British America." 497.

The glacialists generally find no cause for the great ice sheet, whose effects they see, in the elevation of the mountains, or in ice floods, nor in ice rafts floating from the pole. Mr. James Croll finds its cause in the earth's movement in an elliptical and eccentric orbit round the sun, which is central to one end of the ellipse, so that when the earth moves in the other end of the ellipse it is three millions of miles farther from the sun, and in the extreme of the orbital eccentricity he says fourteen millions of miles further from the Sun; and by reason thereof the warmth of the Sun is lessened at its surface. At this time the Earth is nearest the Sun at our mid-winter, and our winter solstice is supposed to be warmer for it; but by the precession of the equinox, the Sun crosses the equator twenty minutes and twenty seconds sooner than the year before; Geikie 129; by which process our seasons become gradually shifted in relation to the position of the Earth in its orbit, so that in ten thousand five hundred years our winter

solstice will coincide with the Earth's greatest distance from the Sun; 13); hence, greater refrigeration; and hence, according to Jas. Croll, a great ice cap at the North Pole; to be yet more aggravated when such coincidence shall occur at the greatest eccentricity of the Earth's orbit. It is not asserted that in any one year the Earth will receive any less heat from the Sun, or in either hemisphere than in the normal state of the Earth's movements. If the aphelion winter be colder, the perihelion summer would be warmer in the same hemisphere. At the present time these both occur in the southern hemisphere, and we hear of no abnormal cold, or increase of ice. Certainly South America is not invaded by ice, and our ships are going round Cape Horn as usual. It is not known that the glaciers on the Andes have grown higher or longer; while it is known that by the rise of Norway of but three feet in a century, the mountain glaciers have grown longer by about three hundred yards. The good people there need not be in a hurry to emigrate, for in due time the vertical oscillation will be in an opposite direction.

Agassiz says, in his *Journey in Brazil*, in proof of his opinion, "On my arrival in Rio de Janeiro, * * * my attention was immediately attracted by a very peculiar formation consisting of an ochraceous, highly ferruginous, sandy clay. During a stay of three months at Rio, whence I made my excursions into the neighboring country, I had opportunities of studying this deposit, both in the province of Rio de Janeiro and in the adjoining province of Minas Geraes. I found that it rested everywhere upon the undulating surfaces of the solid rocks in place, was almost entirely destitute of stratification, and contained a variety of pebbles and boulders." p. 299. "There can be no doubt in the mind of any one familiar with similar facts observed in other parts of the world, that this is one of the many forms of drift connected with glacial action. I was, however, far from anticipating, when I first met it in the neighborhood of Rio, that I should afterwards find it spreading over the surface of the country from north to south and from east to west, with a continuity which gives legible connection to the whole geological history of the continent." p. 400. "A sheet of drift, consisting of the same homogenous, unstratified paste, and containing loose materials of all sorts and sizes, covers the country." p. 403. Up the coast at Pará, he says, "I was surprised to find at every step of my progress the same geological phenomena which had met me at Rio," and he was reliably informed "that this formation continued through the whole valley of the Amazons, and was also to be found on all the affluents." p. 405. Now Rio is at the 24th degree of south latitude, Pará at one degree, and the Amazon discharges under the equator. Did then the polar ice cause the phenomenon? If so, was it by a mighty continuous land-borne glacier from the South Pole, or by ices from the Andes, glacial or floating? He gives no explanation here, but elsewhere regards the Andes as sources of the glaciation. He saw the unstratified paste "spreading over the surface of the country." Other geologists, in other parts of the world, find its supposed equivalent, the "boulder clay or till," at the bottom of the drift

formation, and long antecedent in deposition. But there is no reason why the paste should not be formed through all time, where there are mountain glaciers, grinding the rocks of the descending defiles, with a water under-flow, frosts and rains, to spread it over the lower country, to an indefinite extent through indefinite time.

There certainly seems to be no warrant for the supposition of a polar ice-sheet over South America, while a cause for the phenomena seen seems much nearer. There are the Cordilleras, ever ice-covered, with valleys filled with glaciers grinding upon the rocks, and making paste or Till of their comminuted materials, and incessant freezings and thawings and rains to carry down the product over the *surface of the land*, now as well as when the first drift deposit was made. Further information is certainly wanted upon this subject, and it may be hoped that Professor Orton, now about to visit the Amazon, may afford it. Mr. Kerr, in his Report on the Survey of North Carolina, in 1875, makes observations pertinent and interesting: "Till or initial drift," which "may be seen everywhere on the hills and slopes of the Piedmont region, and less conspicuously, even in the eastern territory of the Quarternary proper." p. 157. "Evidently these materials" (the gold gravels) "have descended the slopes of the mountains and ridges, at whose bases, or on whose lower and gentle inclines they are found. By what force? Certainly not of water. Neither are they moraines; accumulations at the foot of descending ice masses. They are simply beds of *till*, which have crept down the declivities of the hills and mountains, exactly as glaciers descend the Alpine valley, by successive *freezing and thawing of the whole water-saturated mass, both the expansion of freezing and gravitation contributing to the downward movement*; and with each thawing and advance, the embedded stones and gold particles dropping a little nearer the bottom." p. 156. This idea may explain much of the appearances that perplex geologists, without driving them to the theory of an immense polar ice-sheet glaciation. All past time, since the mountains rose from the sea, gives room for normal causes to complete their work, with the results we witness; and account for Till being found upon the surface as well as beneath the drift, and that without a polar ice-sheet.

Those who concur in the conclusion that there have been continental ice-sheets of great thickness, and destructive of all life where they moved, are not agreed as to their cause, source, or extent. Agassiz insists that their cause is cosmic, and more than the normal glaciers of high mountains; and he and James Croll, and Winchell, and others, give them a polar center and a flow towards the tropics down to at least the 39th degree of latitude, and Agassiz extends them into the tropics. James Geikie, with Croll, ascribes to them an astronomical cause, but makes the mountains of Norway and Sweden the source and center of the ice-distribution. Winchell infers a mountain at the North Pole adequate to the production and movement hither of the great ice-sheet. This want of accord among these eminent glacialists is an argument of considerable force to show that the theory is without a tenable foundation.

Beside, the theory is so extraordinary, in its conjectured cause, and so stupendously disastrous in its consequences; and so wholly at variance with the ordinary procedures of Nature, that mankind have a right to take their stand on the stability of normal laws, and to demand the clearest and most indubitable proofs, before they yield their faith in all they have been taught by experience and history.

Uniformity between cause and effect; stability of law; are the basis and surety of all philosophizing. Building on such foundation mankind have believed that this earth is their stable habitation, since man was placed here, and that it is neither to be drowned nor ice-clad, to the destruction of the life upon it. We reasonably infer from all the past that the world was made to support the life it sustains; that the Power that could create both it and that life, and adapted one to the other, had a purpose of their permanence, and would not permit that purpose to become frustrate. Against such an inference, based in all knowledge of what has been, they who assert an impending liability to the destruction of half or more of the human race, with its wealth and civilization, have a right to demand an attesting example in the world's geological history, or reasons more cogent than seem to have been offered, to prove that such destruction awaits the world.

They have a right to say that so general a disaster is not compatible with the established order of the universe. Those who offer an hypothesis, the converse of this ground of security, have the burden of the proof and of the argument resting heavily upon them. The facts they rely upon must be clearly incapable of any other solution; the cause assigned must fit the effect.

All physicists profess to adhere to the normal laws of nature; as the law of gravitation, the movements of the planets, &c., the formations of the rocks, their elevations and depressions; of evaporations, and rainfalls, and congelations, &c.; and he who rests himself on such foundation is to be taken to be upon the true foundation, until it is clearly shown that some eccentricity of nature has been acting exceptionally, and has left the evidences of her exceptional action in manner to be incapable of explanation by her usual laws. Adhering to these laws geologists have generally agreed that in the beginning this Earth was very hot and that its interior was the source of igneous rocks; that it was surrounded by water and steam; and in the pervasive waters the sedimentary rocks were deposited from the eroded materials of igneous rocks, and by incessant repetitions of the erosions of both kinds of rocks, and that as late as the Carboniferous Ages the Arctic had yet a Tropical climate. By heat the Earth was kept expanded, but cooling by radiation it gradually grew less, and the crust of rock became too large for the internal mass, and consequently by its own weight the collapse sunk the valleys and raised the hills, formed the ocean beds and heaved the mountain ranges, and the Earth's rocky covering became plicated and corrugated, yet by a process as gradual and quiet as the radiation of the internal heat. This process was onward until its cause ceased; but the cessation of the radiation was no cause for a glaciation

greater than we witness. By the impulse that produced the rotation of the Earth on its axis, the shape of the globe was reduced from a sphere to an oblate spheroid, by the flattening of the Poles, and that cause forbade mountains rising at the Poles. It is necessary that we keep the above principles and facts in view as we proceed. The height of mountains, and seas open to the Poles are both causes of glaciation, and not to be overlooked, but cannot be cause of the continental ice-sheet.

Having stated the theory of the great glacial ice-sheet, and the facts upon which the glacialists place it, it seems expedient, considering how generally it has been accepted, to take yet closer and broader views of other facts and laws requisite to correct conclusions, many of them furnished by the glacialists themselves, but looked at by other eyes, these may afford proofs that should conduct to an opposite induction.

The *unstratified drift*, or boulder clay, or Till, is a chief argument for the continental Arctic sheet of ice. Grant it came from beneath ice, that fact does not prove that it came from a polar ice-sheet, for it might be from glaciers of contiguous mountains, or ices floating down from the North. Dr. Dawson says: "It may be viewed as consisting of a base or paste including angular and rounded fragments of rocks. The base varies from a stiff clay to loose sand, and its composition and color generally depend upon those of the *underlying and neighboring rocks*. Thus, over sandstones it is arenaceous, over shales argillaceous, and over conglomerates and hard slates, pebbly or shingly. The greater number of the stones contained in the drift are usually like the paste containing them, derived from the neighboring rock formations." *Acadian Geology*, 59. In Brazil it is "ochraceous, highly ferruginous, sandy clay." Agassiz, 399. This is evidence that the source of the Till is local and co-extensive with a local cause and source; but as the Andes are of immense height and running the length of South America and covered by perpetual glaciers, so the manufacture of the paste is present through all time; and the frosts and rains have ever since the Cordilleras were raised, spread it over the declining surface towards and to the Atlantic. With this eternal winter ever present upon the Andes, even under the Equator, it does not seem necessary that we should seek a cause in a great "cosmic winter," "of universal cold," which may have lasted "for thousands of centuries," for so much Agassiz says. We need not then go to a polar ice-cap for an explanation. The Till may be there from normal causes, and thus be yet spreading over the surface.

Agassiz rejects the idea of deposition under the sea, because there are no marine remains in the strata of rocks or their covering. He says: "It is my belief that all these deposits belong to the Ice Period in its earlier or later phases, and to this cosmic winter, which, judging from all the phenomena connected with it, may have lasted for thousands of centuries, we must look for the key to the geological history of the Amazonian Valley. I am aware that this suggestion will appear extravagant, but is it, after all, so improbable, when Central Europe was covered with ice thousands of

feet thick ; when the glaciers of Great Britain ploughed into the sea, and when those of the Swiss Mountains had ten times their present altitude ; when every lake in Northern Italy was filled with ice, and these frozen masses extended even into Northern Africa ; when a sheet of ice, reaching nearly to the summit of Mount Washington * * (that is, having a *thickness* of nearly six thousand feet,) moved over the *continent* of North America ; is it so improbable that, in this epoch of *universal cold*, the Valley of the Amazons also had its glacier poured down into it from the accumulations of snow in the Cordilleras, and swollen laterally by the tributary glaciers descending from the table lands of Guiana and Brazil? The movement of the immense glacier must have been eastward, determined as well by the vast reservoirs of snows in the Andes as by the direction of the valley itself. It must have ploughed the valley bottom over and over again, grinding all the materials beneath it to a fine powder, or reducing them to small pebbles ; and it must have accumulated at its lower end a moraine of proportions as gigantic as its own ; thus building a colossal sea wall across the valley." p. 425. But he found no striated stone as there was no natural rock-surface in the valley ; and admits "I have not here the positive evidence which has guided me in my previous glacial investigations." p. 426.

All this account of the Amazonian Valley is inconsistent with what Mr. Agassiz had, in the same Journal, 403, said of a Northern and Southern Ice-cap "moving to the Equator," and with all the other glacialists who claim that it did not descend below the thirty-ninth degree of latitude. This gigantic glacier certainly did not come from the South Pole ; nay, when in the stage of thawing, it did not move at all. It was dammed in by its own moraine or huge wall of *débris* ; and when it melted it became a vast fresh-water lake. And Agassiz says : "In this shallow sheet of water under the ice, and protected by it from any violent disturbance, those finer triturated materials always found at a glacier bottom, and ground sometimes to powder by its action, would be deposited and gradually transformed from an unstratified paste containing the finest sand and mud, together with coarse pebbles and gravel, into a regularly stratified formation." Ib. 428. This is said to explain why this is not like the same glacial product in Europe ; why it is stratified as a deposit of still waters, but does not explain how the same material has a different appearance over the general surface of Brazil ; how the trituration and stratification would go on without motion of both ice and water, nor what, during such quiet lake-like operation under ice, had become of the floods that were ever descending from the greatest water shed of the world which must reach the sea. The attempted theory demands too much, involves difficulties not cleared up, and stands upon another basis than that of polar glaciation. That the floods of the Amazon and all its tributaries should be self-dammed into a lake of fresh water, and, at near the sea level, covered with ice under the equator is a proposition that seems of the most extraordinary nature, and self-condemning.

Let us proceed to examine other witnesses for additional facts, and compare other opinions of the scientific experts, though it be to find them expressing conflicting views, as they are wont to do in courts of justice, when it becomes the duty of the judge to extract the truth as well as he can, by principles of reason applied by good sense. The testimony will keep in view not only the facts of glaciation, but also those which show that there were other causes for all the phenomena we witness less abnormal than that assigned by the eminent naturalist whose name gave authority to all his utterances. If a continental ice-sheet of the magnitude supposed could not travel hither from the North Pole by land, there may have been water-ways for ice to float down from the Arctic region, and also local glaciers from higher mountains where none are now to be found, or those of much smaller size.

If the glaciation was cosmic, polar and continental, then should Northern Asia bear evidence of it. James Geikie claims to include North America, but does not claim Siberia as having been subject to the reign of ice. He says: "Thus, in the Western as in the Eastern Hemisphere, we are confronted with precisely the same phenomena. In regions which can be proved never to have been over-riden by the great continental glaciers, and in districts which give no evidence of submergence during the latest period of glacial cold, the extinct mammalia occur in less or greater abundance at the very surface." *Great Ice Age*, 501. He further says the north coast of Asia "indicates the former presence of a milder climate in Siberia than now," "in the presence of numerous animal remains," as of the "mammoth, woolly rhinoceros, bison and horse." p. 495, 496. "The great plains of Siberia never could have nourished glaciers." "The absence of high grounds, and the comparative dryness of the climate, must have prevented any accumulation of glacier ice." 502. And he only claims that the great glaciers extended southward to the middle of England. Yet to fill the conception of Agassiz and Croll the ice formation at the North Pole should have so filled the Arctic Ocean as to move by its weight over the land of Northern Asia, as well as over Europe and America. The land journey should have been the same over the three continents from the same mountain of ice at the North Pole.

Next to the boulder clay, the scratches and groovings in the rocks are taken as the proofs of the Polar ice-sheet. Their straight northerly direction affords the argument.

Dr. Dawson, an eminent practical geologist, who has observed by travel and reflected much upon the subject, rejects the theory of the great ice-sheet from the far north. The scratchings are not from one direction, but some from nearly north, some from north 20° and 30° east, north 20°, 25°, 30° and 65° west. *Acadian Geo.* 62; 69. In the St. Lawrence Valley the direction is from northeast to southwest. At Stony Point, Lake Erie, Michigan, the grooves are from north 60° east, and from north 60° west. Winchell, 218. Dana gives greater variations, showing variations and hitches in the moving mass. 539, 751. And Henry D. Rogers said, the

grooves crossed at various angles, and "the striae are, moreover, not rigorously straight, but curve slightly to conform to inequalities in the shape and hardness of the resisting surface." 2 Geo. of Penna., 775.

Dr. Dawson says: "I have no hesitation in asserting, from my own observations as well as from those of others, that for the southwest striation the direction was *from the ocean toward the interior*, against the slope of the St. Lawrence Valley. The crag-and-tail forms of all our isolated hills, and the direction of the transport of boulders carried from them show throughout Canada the movement was from northeast to southwest. This at once disposes of the glacier theory for the prevailing set of striae, for we cannot suppose a glacier moving from the Atlantic up into the interior. On the other hand, it is eminently favorable to the idea of ocean drift." 69. This was based upon the idea of a submergence of Canada, New York, and New England, and an Arctic current bearing ice in the forms there produced. He proceeds to say: "Now we know that in the Post-pliocene Period, Eastern America was submerged, and consequently the striation at once comes into harmony with other geological facts." 70.

Dr. Edward Hitchcock, in his address in 1841, says: "The group named post-tertiary by Mr. Lyell, is found also in the northern part of New York and in Canada, containing shells of a more Arctic character than those now living in the same latitudes." p. 18. To produce the drift, scratchings, and transportation of boulders witnessed, the agents must have been water and ice, exerted before the existence of man on the continent; yet geologically recent; but he did not pronounce his belief in the great ice-sheet. 22, 23.

Professor Rogers says: "From the coast of Maine westward to the basin of Lake Ontario, and from the estuary of the Hudson northward to that of the St. Lawrence, a deposit of blue clay and sand occupies the valleys of many of the rivers at all levels above the tide and to a height of more than four hundred feet in the Valley of Lake Champlain, where its elevation is at its maximum." And speaking of the later local drift, he says: "No one general direction or northern source can be assigned to this upper deposit, *its gravel and erratic blocks appearing rather to be derived from the more ancient general drift of the adjoining hills, redispersed by some aqueous movement upon the surface of the fossiliferous clays and sands.*" 2 Geo. of Pa., 775.

To proceed with our survey geographically from east to west. The Geology of New Jersey by George H. Cook presents us with some relevant information. He says: "After the process of deposition had ceased, the whole of this ancient shore has been elevated to nearly four hundred feet above the ocean level. This has taken place bodily." But, "Some powerful agency like that of water, or water and ice, has swept over the whole country, and has worn down its surface in gullies, valleys, or broader intervals, sometimes to the amount of three or four hundred feet." p. 285. He gives twenty-four observations of scratches on the Traprocks. Of seven on the Palisades their course is south 20 to 40 degrees east; Bergen

Neck southwest and southeast ; south and west of Patterson south 60 to 75 degrees west ; Second Mountain and Rook Mountain southwest and 15 to 65 degrees west. p. 228. "The stones and boulders are in many cases from distant localities," those containing fossils are found in place only on the northwest side of Kittatinny Mountain. 229. "Two skulls of the walrus, an animal living only in the polar seas, have been found in the gravel near Long Branch." p. 342. "These were, no doubt, ice borne ; the question is whether by floating or creeping ice? Parts of South Carolina has undergone a similar denudation of one hundred and fifty feet. Tuomey's *Gel. Rept.* 102. All these are evidences of the doings of ice, and of currents of water from the northward, and not of the rigid movement, and grinding, leveling power of a gigantic ice-sheet.

British America, north of and including Canada, is generally a plane ; its lakes being from three hundred to eight hundred feet in height ; and the chain of great lakes bounding the United States are from two hundred and thirty-two to six hundred feet, the height of Lake Superior ; so that the rise between Quebec and the west end of that lake, twelve hundred miles, averages six inches a mile. *Survey of Canada, 1863, p. 6, 7.* A table of one hundred and forty-five glacial grooves is given in the *Survey of Canada*, with a general southern direction, p. 890, of which eighty-four range west of south, some of them from 45 to 76 degrees, and fifty-seven range eastward, some of them from 45 to 80 degrees, or approaching an east and west direction. These are in Southern Canada, below 50°36' of north latitude. Along the Ottawa the furrows conform in a general way to the direction of the river valleys, the limits of which appear to have guided the moving masses producing the present grooves." *Ib.* 889.

The superficial deposits in the vicinity of Montreal show former sea margins at the heights of 470, 440, 386, and 220 feet over the sea level. *Dr. Dawson, Geol. Report of 1863, p. 918.* Below the lowest level and about one hundred feet above the St. Lawrence, or one hundred and twenty above the sea, are the stratified deposits of gravel and fine-grained sand ; then comes a calcareous gray sand, which rests upon the boulder clay, which is filled with rounded and striated fragments of various rocks, all of the thickness of about one hundred feet, of which the boulder formation is the greater part. The rocks beneath are polished and grooved. The boulders were drifted southwestward, and came from 40° to 70° east of north. *Ib.* — Yet, towards the mouth of the St. Lawrence, a Gaspé boulder of limestone, 40 feet in diameter, has been moved several miles north or northeastward, and blocks of granite from Table-topped Mountain down Magdalen Valley several miles northeastward. *Dr. Dawson described similar instances of northward transportation of boulders in Nova Scotia. Ib. 803.* The White Mountains were at long distance of time twice elevated, first by a force from north 80° west, then from south 10° east, which indicates the thrusts of oceanic depressions from the west as well as from the Atlantic. See *C. H. Hitchcock's Rep. to N. Ham. Leg. for 1871, p. 9.* It is thus seen that Canada as well as New England and the Mississippi

Valley rose from the ocean, and at different elevations the abraiding ice had different directions.

By the Ohio Geol. Survey, vol. i, p. 538, it appears that of the striae across the islands in the west end of Lake Erie and in the Maumee Valley, sixteen observations in eight counties, have a bearing south 80° west to 35° west with two intersecting grooves south 15° west. At West Sister Island the glacier moves westward, the pressure and planing being greatest at the east front, while on the opposite shore the undulating surface of the rock has been merely scratched. p. 539. The limestone rocks of that island contained imbedded flint nodules, which offered a greater resistance to the ice. On the "lee" side of each is a long ridge in the limestone by reason of the protection of the hard flint. This phenomenon, says Mr. Gilbert, "seems to afford a better explanation of the long, smooth, even furrows so frequently seen, than the theory that they have been engraved or ploughed by large boulders;" p. 540; that is to say, the rocks were ground by the ice.

Dr. Newberry describes the drift deposits of Ohio, and as to the lowest says, the "sheet of clay and boulders I have termed the Glacial Drift because it seems to be the direct product of glacial action." p. 86. Scattered over the drifts are numerous boulders, often of great size. They must have "been floated to and dropped upon their present resting places. In my judgment no other agent than *floating ice* could have accomplished their transport in the manner in which it has been done. Hence, I have considered them as the result of iceberg action, and have termed them and the northern gravel with which they are associated, the *Iceberg Drift*." 87, 183; 2 vol. 4.

Pursuing the Ohio Survey into the second volume of 1874, Dr. J. S. Newberry gives many pertinent observations and reflections: "In Ohio we have no geological formations intervening between the Carboniferous and the Quaternary." The reason, "about the close of the Carboniferous Age the Allegheny Mountains were raised, carrying up all the area lying between the Mississippi and the Atlantic. From that time to the Quaternary no part of this region, with the exception of the southern margin, was ever submerged." "West of the Mississippi the land has been often and long below the ocean level since the epoch of the coal measures." "The materials which accumulated during the Quaternary are beds of clay, sand, gravel, and boulders, which have received the name of *Drift*." "The drift deposits cover nearly all parts of the State." p. 1. He holds that the rocks were planed down to latitude 40 by glacial action. p. 2. The lowest drift deposit, "though not always present, is a tough, blue, unstratified clay, generally thickly set with small stones; more rarely containing those of larger size, ground and scratched;" hence, called the boulder clay. "In certain localities the pebbly 'hard-pan;' or boulder clay, is overlaid by a greater or less thickness of fine laminated clay, without pebbles;" and these blend so as to leave no line of demarcation, and together are called *Erie clay*. Above is the *Forest Bed*. p. 3. "In Western Ohio, In-

diana, Illinois, &c., the uppermost strata of the drift is called the Loess or Bluff formation." These "are the products of the last submergence, and I have termed them the *Lacustrine Drift*." Upon these "are scattered boulders and blocks of all sizes of granite, greenstone, silicious and mica slates, &c., &c., &c., generally traceable to some locality in the Eozoic area north of the lakes." "The boulders are found on nearly all the drift-covered area of the State; being carried over the summit of the water-shed, and reaching south nearly or quite to the Ohio. The margin of the boulder area seems to mark the outline of the great ice-sheet at the period of its greatest development; but *most of the boulders* strewed over this area, *appear to have been deposited by another agency*, at a much later date." They lie near the surface, often over purely laminated clay, "and hence could never have reached their present positions through the agency of glaciers or powerful currents of water. They must, therefore, have been *float*ed to their present resting places. The evidence is conclusive that they were transported by icebergs, and hence I have called them the *Iceberg Drift*." p. 4.

Dr. Newberry gives 87 observations of a system of grooves confined to the lake basin and the northwestern counties of the State, from which he says "the prevailing direction of the stria is 10° south of west," and remarks "that in this portion of the State a series of glacial marks which have a nearly north and south bearing, are obliterated by the stronger, fresher, and more numerous grooves of which the bearing is nearly east and west. As I have shown elsewhere, the striæ which cover the highlands and southern portions of the State were probably made by the continental glacier which existed during the period of greatest cold, and which had in Ohio a movement from north toward south and southeast; while the glacier which moved from east westward in the lake basin was a *local glacier of later date*, and the one by which the excavation of the lake basin was principally effected." 2 Ohio, R. 10.

"It seems that in the period of greatest submergence the larger part of the summit of the water-shed was under water." "At this time a sufficient depth of water existed in the passes of the water-shed to float icebergs of considerable size, and as currents flowed through these passes, some of the boulders scattered over Southern Ohio were probably transported by them." Five of these passes are noticed; marked "by deeply excavated channels, now more or less perfectly by great accumulations of rolled and transported material, such as would be the natural product of a copious flow of water, continued through ages of time, and gradually diminishing and losing its transporting power." p. 47. These out-lets carried the waters southwestward into the seas or lakes of the great Mississippi valley. The Niagara River and Falls then were not. p. 52.

"The boulders belong almost without exception to the chrysaline and igneous rocks that are found *in situ* only to the north of the great lakes." p. 26. None are from east Canada or Labrador; but nearly all "can be traced to places of origin in localities north and northwest of Ohio." p. 27.

An inquiry here arises that if floating ice must have been the cause of all the drift and erratics, why should not the same cause have produced the boulder clay? The floating ice could as well do it, as it ground over the ledges of rocks, as an Arctic glacier and the water could better spread the clay as it is found. Such a supposition would obviate a resort to the great ice-sheet for explanation, and avoid other difficulties to be noticed. It is certainly an immense conception of an abnormal cause to explain a limited effect, that seems to have already had its sufficient and acknowledged solution in the cause of every other stratum of the drift.

It is said by Dr. Newberry (2 Ohio Rep. 29), "That the boulder clay was not deposited *beneath* the glacier, as sometimes stated, is apparent from the fact that it covers the glaciated surface on which the ice rested, in a sheet sometimes a hundred feet in thickness. *It must, therefore, have accumulated at the margin of the glacier.*" As the boulder clay is very widely spread, as well as often of a great depth, the more natural inference would seem to be that it was spread by the waters, as ground from the rocks by floating ice-rafts, and afterwards yet more dispersed by the ocean currents. But the witnesses do not always agree with themselves or with each other upon this subject.

The 2 Volume of Ohio Rep. in its Chapter L., contains views at variance with the theory of "the glacier," contributed by Mr. E. B. Andrews. He says Professor Hopkins expresses the belief that the boulders found on highlands of the 2d Geological district, were transported by floating ice-rafts, "and not by a vast, continuous northern glacier," and that drift materials were carried down to the lower Mississippi district. And Professor Hilgard thinks that "the phenomena observed in the Southern States are but the necessary consequences and complements of the drift phenomena of the North," and says it is time "that the Ohio should cease to be proclaimed as the southern limit of the drift." p. 451. Mr. Andrews speaking of the southeastern part of Ohio says, we have seen "there is no evidence that the pre-glacial or ante-drift surface *was essentially different from what it now is.* If there was a climate so arctic in character as to allow of the extension of a sheet of ice immensely thick almost to the Ohio River, we should expect that the same cold climate would necessitate glaciation in the Allegheny Mountains, but a short distance south of the Ohio, where no traces of glaciers have been found. The average altitude of the Allegheny range is 3,000 feet. If, on the other hand, the cold were produced by marine currents coming down from the Arctic region, it would have the sharp limitations characteristic of such currents at the present day." "Local glaciers are freely admitted to have existed on the higher grounds adjacent to the icy northern currents." p. 449. Mr. Andrews quotes the strong views of the Duke of Argyle, President of the Geological Society of London, against the glacial sheet, as satisfactory. p. 450.

In the Geological Survey of Illinois, of 1873, the northwestern section is described by James Shaw. He says, "That vast glaciers of ice once extended over large portions of North America is now universally conceded.

Their slow, crawling motion and irresistible force ground the rocks to powder, as wheat is ground to flour between the upper and nether mill-stones; not only ground them to powder, but rounded and polished the boulders and the gravel, planed and grooved the rocky surface of the earth, and moved the vast masses of drift materials from place to place in slow procession." 5-6. "But the great mixing and transporting agency which arranged, assorted, and deposited our Northern Illinois drift deposit, was evidently *the mixed action of ice and water.*" 6. The first and greatest force was the glaciers of the high lands; "then the floating iceberg and ice-field produced by their results, carrying the large boulders from place to place, and dropping them over the ice-cold seas; and last, the wave and current forces of water, after the ice had in part, or altogether melted, left loose clays, sands and sub-soils, substantially as we find them now." 6-7. "Eroding and denuding influences have removed from three hundred to three hundred and fifty feet of Magnesian limestone and shales." "The dynamical powers of heavy bodies of water and water currents, and other drift forces, must have acted long and powerfully in bringing them about." 31, and see 32. "A mixed mass of gravel * * would seem to indicate that forces from a distance and forces near at hand, operating in every conceivable direction, with great force and over long periods of time, all contributed to gather together these heaps of abraded materials, some from the distant regions of the granite and the traps, and some from the neighboring limestones of a by-gone geological age; but all equally worn smooth by the grinding of the waters and ice." 109. "Whether the floating iceberg, or the slow crawling glacier, or the strong water currents, or all these combined, transported the coarser materials of the drift, the force of the powerful agents were much modified in their action here." 145. It would seem that the other powerful causes stated, might suffice, if "the slow crawling glacier were omitted; and this is the opinion of Mr. E. B. Andrews; assistant in the Ohio Survey, 2 Vol. 447. He says, "There is no general planing off of the rocks; but everywhere among the hills where the northern boulders are most abundant are projecting knobs or outliers of soft rocks, which would naturally be an easy prey to such a destructive force as would be exerted by the movement of a vast glacier." 448.

Moving westward we reach Wisconsin, Iowa and Minnesota, upon which David Dale Owen made his Geological Report, to the U. S. Government in 1852. Among the materials of the drift the "trappean rocks are much the most common." "They originated at the time of the upheaval of the trap, and at comparatively a recent period. There are facts ascertained which render it probable that a large area of the Northwest Territory has been raised during very modern periods, even since the present fauna inhabited its rivers and lakes." "There is a gradual drainage of its waters taking place, even at this time." p. 143.

"In the vast prairie region of Iowa, the attention of the geologist is frequently arrested by erratic blocks of enormous dimensions, scattered here and there, and half sunk in the ground." "They are far from their

original situation." "The only explanation that is at all satisfactory in accounting for the transporting power which has brought detached masses of granite rocks into their present position, is *floating ice*; ice drifted by currents setting from the north, before the land emerged from the ocean, in the same manner as, at the present time, thousands of tons of rocks are precipitated on the bed of the Atlantic Ocean from icebergs." "Their isolated position in the prairie also indicates that they were dropped into their present positions rather than rolled into it." 144, 145. "The clay-beds are often thinly laminated, at some exposures, the laminae are wrinkled. They conform in their dip to the general undulations of the country." p. 298. This, of course was after the depositions.

Charles A. White's first annual Report in 1867, to the Iowa Legislature, speaks of meeting with some striæ on the bluffs which border the bottom lands of the Missouri River; the coarser set (No. 1), S. 20° E.; the finer (No. 2) S. 51° E. Set 3 below Omaha is S. 41° W. p. 144. The direction of the scratches No. 3 observed coincides pretty nearly with general direction of the western watershed of the State; "and sets No. 1 and 2 respectively represents currents approximately coinciding with the general courses of the Missouri and Platte Rivers." p. 145. Diversity in the direction of the grooves, passing from all northerly to all southerly points, and in conformity with the trend of valleys and water-sheds, favor the theory of the cause being floating ice rather than the rigid gigantic ice-sheet that would hold its course onward against all obstructions, according to the glacial theory.

Professor Hayden has occasionally noticed the action of ice during his recent explorations in the far west, but the striations have been mostly from the valley glaciers in the mountains. He says: "Along the Platte River, below Omaha, and on the Missouri, near the city, the carboniferous limestones have had their upper surface so thoroughly smoothed by glacial action that they can be quarried out and used for caps and sills without any further finish of them." Report for 1870, p. 99. "There are a few small grooves or scratches, and * * I ascertained their direction to be about 27° west of north." All the limestones round Omaha, under the yellow marl and pebble deposits, were so smoothed. "In the mountains proper, the evidences of glacial action are not uncommon, especially on the sides of the deep valleys and gorges, but the causes were local and operated when the temperature of the climate was much lower than it is at present." p. 100.

Speaking of the eastern portion of the Rocky Mountains, source of the Arkansas, Professor Hayden says: "Perhaps the most interesting and novel features of this region are the great morainal deposits, the remains of ancient glaciers. These proofs of glacial action occur everywhere along both the east and west sides of the great Sawatch or Mother Range. But up the valleys of some of the side streams the morainal deposits are more marked and regular than in others." Report for 1873. Speaking of the Park Range, the gentle slopes are on the east side, the west sides very

abrupt, sometimes the rocks overhanging indicating that they are a portion of an anticlinal. Ib. 39. So our Appalachians and Atlantic seaboard hills lean from the Atlantic Synclinal, as if the upheaving force was in the sinking bed of that ocean, or as one preponderated in the balance the other rose.

One other great feature of structural geology is to be noticed in these Reports. The mountains are built of granite, gneiss, &c. From the Mississippi and Missouri to the Rocky Mountains the stratified deposits of sandstones, limestones, shales, slates, and clays, lie in flat broad sheets, "much as they were when first laid down, one after another in the *bottom of the vast ocean which once existed here*. Since this ocean was gradually drained off, the ceaseless action of the rains and rivers has in places removed thousands of feet of these rocks, exposing beds which were once deeply buried, and in which we can occasionally find the remains of shell-covered beings which still earlier lived and died upon the ocean bottom, or of the skeletons of the animals and plants which peopled the surrounding shores, and were swept by the ancient rivers out into the sea to be buried with the then forming sediments." Dr. Hayden's Report for 1873, p. 93.

And Dr. Newberry, in the United States Report for 1870, says of the lakes that once occupied the region immediately east of the Rocky Mountains: "The sediments that accumulated in the bottoms of these old lakes show that in the earliest periods of their history they contained salt water, at least the sea had access to them, and their waters were more or less impregnated with salt, so as to be inhabited by oysters and other marine or estuary mollusks. "In due time the continental elevation which brought all the country west of the Mississippi up out of the wide-spread cretaceous sea, raised these lake basins altogether above the sea level, and surrounded them with a broad expanse of dry land." p. 329.

But how came such "continental elevation?" Not alone by lifting up the continent bodily, else would the marine deposits have remained at the top and the waters have been drained off, carrying off largely its deposits; but must have been largely raised up by the degradation of higher lands or mountains by freezing, thawing, and erosions, and the flow of the materials into the basin of such sea and lakes, thus preserving both the salt and the fresh water fossils found there in "wonderful" abundance. So were Ohio, Indiana, and Illinois, filled and raised up, and hence, old river bottoms are found far beneath the present surface. And the stratified rocks thus formed have been since cut down into cañons, and even the granites also; all disintegrated both by frosts, heats, and erosive waters, and ice, as well as chiseled by "sand blasts." Hence are there many rocks left perched in the west as in the east, that have never been lifted, or floated by ice, but have simply held their positions after the surrounding strata had been carried away by the above named dynamic causes.

Dr. Newberry further testifies that, "In the progress of the Cretaceous Age, the greater part of the continent west of the Mississippi sank beneath the ocean, and the deposits made during the later portions of the Cretaceous

Age, contain a vegetation more tropical in character than that which preceded it. It seems probable that at this time the lands which existed as such at the west of the Mississippi, were islands of limited extent, washed by the Gulf Stream, which apparently had a course north and west from the Gulf of Mexico to the Arctic Sea." Prof. Hayden's Geological Survey of Wyoming, &c., for 1870, p. 336. It will not be forgotten that the tropical vegetation spoken of, was due to the warmth of the Gulf waters flowing to the northwestward, and perhaps, the Earth's interior heat, yet un-radiated.

As by the discrimination made in the west by which all the drift above the boulder clay is ascribed to *floating ice*, so by the same rule the sand and boulders of New England should be ascribed to the same cause. They should be regarded as water-rolled and water-borne in ice rafts as they appear to have been, when existing mountains there were at different heights, and where the lower ridges were not so high nor the valleys so deep as now, and all but the highest mountains were under water, so that the excoriations would be the more continuous, and the rocks lifted from one ridge be carried upon another or dropped intermediately; reaching Long Island and the sea, or let fall at Stonington, or in the Sound and bays. Thus they might have been carried to ridges now higher, without violating the law of gravitation, as the latter may have risen disproportionately, as did the White Mountains compared with the Green. In Ohio, Indiana, and Illinois, they had not such mountains to gauge the rise of the land as in New England, by the water level, as shown by the grooves of transported ice, but the water at the west left the proofs that it was the agent that shaped the surface of the country more perfectly than the ice-sheet would have done. Dr. Newberry speaking of the five gorges in Ohio, that gave outlets to the water towards the southwest, says: "Each of these gorges is now more or less filled with drift, but the remarkable similarity of level which they present will strike the most casual observer, and will not fail to suggest their reference to *a common producing cause*. All the lines of drainage leading southward from these passes are marked by deeply excavated channels, now more or less perfectly filled by great accumulations of *rolled and transported material*, such as would be the natural product of a copious flow of water continued through ages of time, and gradually diminishing and losing its transporting power." 2 Ohio Rep. p. 47.

Dr. Newberry speaks of repeated vertical oscillations of the surface: says, "The withdrawal of the water of the last submergence of the drift took place slowly, and its progress was marked by periods of rest, and perhaps, of recession;" hence, the *Terrace Epoch*. Ib. 50. The ice period was one of an elevation of several hundred feet. It was followed by a water period and warmth; the continent five hundred feet below the water level. The first deposit of this period was the boulder clay. p. 6. This would seem to make it a deposit under water. Then came the laminated clays, on this came the forest and peat beds, which of course grew in the air. After these may have grown for hundreds or thousands of years, a submergence

of the continent took place. During this, the *clays, sand, and gravel were deposited; floated down by icebergs from the Canadian highlands*, with blocks of granite, greenstone, slates. See p. 7. Yet "the glacier" is credited with having carried large blocks of lime and sandstones "one hundred miles or more southwest to points several hundred feet above their place of origin," from the north or islands within Lake Erie. p. 29. In view of all the circumstances it would seem more natural to infer that these large stones were transported by floating ice-rafts and deposited on ground that was *afterwards elevated*, as it often was by an interior force.

Again, Dr. Newberry says: "At the commencement of this ice period this continent must have stood several hundred feet higher than now." 2 Ohio Geo. Rep. 6. That the first product in Ohio of the ice period, was the boulder clay. And that in New England and other countries where granite and other silicious matamorphic rocks abound, the product of glacial erosion is sand, gravel, and boulders. As the great ice sheet retreated northward it thrust out and left behind it a succession of heaps of boulder clay which now form a nearly continuous sheet over the glaciated surface," Ib. These quotations present some difficulties. If the continent was several hundred feet higher at the commencement of the ice period than now, so much greater would have been the difficulty for ice to come hither from the Pole by land; whereas if it was then under water, as under the next coming drift period, such a rise was unnecessary to account for the Till which might be the product of floating ice; that would also dispense with Mr. Winchell's mountain at the Pole to make an incline for the ice to come down by gravity. And, again, it is not perceived how a northwardly retreating ice-sheet, that is, retreating only because and as it melted, could have *thrust out* and left behind it the boulder clay, bearing all the evidences of having been spread out and deposited under the action of pervasive waters. Indeed, Dr. Newberry seems to have raised the continent once oftener than necessary, if the boulder clay could have been deposited under the sea as he admits the drift and many boulders were.

Now, seeing from all the testimony cited, that Canada and all directly to the north, was under the ocean; New England also, except the highest tops of the mountains; and the great Mississippi Valley was also an extension of the Gulf of Mexico; that there were no great Mountains northwards of Canada, nor in Canada, but an ocean current bore thence southward dividing southeastward over New England, and westward and southwestward over the country lying between the Rocky Mountains and the Alleghanies, what is so likely to have been the source of the Till, the boulders, the drift, and rock groovings as the northern ice borne upon the northern oceanic currents? There may have been icebergs broken from Arctic Mountain glaciers, and other ice formations; all floating as ice rafts, thick and of irresistible momentum, grinding upon ridges yet under water and carrying their materials southward.

In view of the preceding facts it seems sufficing to say, that when New England, the Hudson and Champlain Valleys, Canada and the British

Possessions, Ohio and states west and southwestward were under water, and the currents and ices of the Arctic Ocean had full sweep over those areas, we have the conditions to account for all the phenomena witnessed, without resorting to the extremely abnormal cause of a continental ice-sheet. The depression of New England Professor Winchell speaks of in this wise: "The higher summits only held their heads above the careering waves; deposits, bearing the marks of oceanic action reach to an elevation of six thousand feet on Mount Washington, two thousand or more on the Green Mountains, and three thousand on Monadnock." p. 229.- If these measurements had the same sea-datum then their differences record the differences of the mountain depressions, or rather the elevations they had then attained. The same height on Mount Washington is that given by Agassiz as the highest elevation of the ice excoriation; Journey, 425; and that being the greatest ocean height, the conclusion is clear, that it was the edge of ice-sheets that made them, and these could only be floating ice; certainly not stones in the bottom of a continental ice sheet. The inference must further be that as the sea thus registered the greatest depression, or want of elevation of *each* mountain, Mount Washington had been four thousand feet lower than the Green Mountains, and three thousand feet lower than Monadnock; so that there was such depth of water over the valleys and plains as that the Arctic Sea could flow over them, floating either ice-bergs, or belt, or surface rafts of ice. The land it was that was unstable, while the sea kept its level. The supposed gigantic ice sheet needed not to be fifteen or ten thousand feet, or so many hundred feet in thickness, to make those mountain grooves, when the mountains stooped nearly to the level of the sea, or their tops had but peered above the water. All were not equally low, otherwise the highest grooves in all would have had the same level. And so a continental ice-sheet moving on the land already elevated should have scored them at nearly the same level; in either way showing that the mountains had not been sunk equally, or that they had risen unequally. The submergence of New England, with an open interior sea to the pole certainly shows an easier way of accounting for the ice grooves upon the mountains, than to raise a land mountain at the north pole, and an ice-mountain upon the top of that, with a refrigeration to keep the sheet of the thickness of ten to fifteen thousand feet in the "Granite State."

While there are the ice grooves of New England and elsewhere to be accounted for; and these sharply cut, and geologically recent, there seem to be other things visible on the surface quite incompatible with the supposition of a continental glacier of the thickness imagined. The hills of New England, under such a power should have been more leveled down; for a glacier kept hardly frozen could not have much viscosity; it should have crushed the stones into the *moraine profonde*; should have carried few angular erratics, for the mountains to furnish them would be "few and far between," with comparative small elevation. But what do we see there? Huge boulders; rocking boulders; perched up rocks, that would not have been there after such a planing with the gigantic polar-ice plane; and a

surface covered with water-rounded stones of every size and kind, which had to be gathered into stone fences before the soil could be reached for cultivation ; yet so rounded are they that they readily roll out of place, though the base of the enclosure be broad. These are the natural product of a water-covered surface ; of waters floating ice ; which ice may have been thick as Greenland hummocks' ice-belt ice, or glacial icebergs, borne on the arctic current that now comes southward along the eastern side of our continent. We see the evidences that as the ocean retired, the elevation made successively of every part of New England a sea-lashed shore, leaving the drifts that the waters had spread over the sea bottom.

The glacialists seizing upon the one seemingly sufficing adequate cause of a great ice sheet, overlook the difficulties which that theory must encounter to account for that cause, and also other means that may more naturally account for the seen results, without resorting to any abnormal freak or eccentricity of Nature. They may notice that the grooves very generally conform to the trend of the high valleys and water-sheds and to the course of the currents when wide areas were beneath the sea ; denoting the descent of mountain glaciers, or the transportation by water of ice-rafts, or icebergs. They refer not to the transporting power of water in times of ice-floods, when mountain sides slid down, and lakes broke through their moraine dams. They take the presence of irregular boulders in the under clay of the drift as the sure evidence of the work of the polar ice-sheet, while the presence of the like boulders in all the drift, as we see here in Philadelphia, is not taken as proof that all the other strata of the drift had the like cause. The heavy boulders they see at a higher level than their parent place *in situ*, they suppose could only reach their elevations by being pushed up by the great continental ice-sheet because it must obey the pressure of the great ice-head at the pole, and approximating the level of that source of pressure, rises over the secondary mountains of New Hampshire, the Katahdin of Maine, and bridging sounds and inlets of the seas passes into the Atlantic. It is overlooked that those boulders may rest on elevations that may have risen out of the sea from a lower level than the parent quarry ; or may have been shoved higher by the back currents of water that will drive ice-sheets high upon each other when they encounter obstruction ; while on the other hand the ledges of rock that yielded the supply may have sunk lower, by the earth's oscillations, or have been ground down by floating ice, after higher rocks had been carried away.

It is said the glacial epoch was so recent that the mountains were already so degraded as to be near their present height when that epoch came on, and could not have been cause of the effects seen. Now the last glacial epoch is placed many thousand years ago ; Geikie says more than two hundred thousand years. We will not hold him to exact figures ; but take it that was near the time, then it appears to have been ample for the mountains to become reduced from a much higher elevation than their present size, by the operation of normal causes, but anciently acting with greater activity. Now in every year since they rose the height of the

Alps has been lowered by causes that have never for one moment ceased ; and yet more rapidly have the glaciers, which never ceased to flow, worn more deeply their channels. The striae made by the ice on the sides of Monte Rosa and the Bernese Alps show that the glaciers moved at higher elevations relatively to the scored rocks, and adhering to the causes named, we must conclude that the mountains were higher and broader to increase the supply of snow, and that the glaciers moved upon a higher plane, whereby they scored higher tracings on the rocks, and projected further into the valleys below, and carried their boulders to a greater distance. These are causes sufficing for the visible effects, when we add to them to the transporting power of ice-bearing floods, carrying down land slides, and ice-covered lakes, which burst the dams that had sustained them. We need not go to the north pole or the planets to explain the phenomena of the Alps ; except as icebergs floating down from the north would bring an arctic cold with them.

Lyell says "the Alps have acquired four thousand, and even in some places more than ten thousand feet of their present altitude since the commencement of the Eocene period." 1 Prin. 256. He speaks of what they *retain* ; but what height they had at their greatest exaltation no one can tell, for upheaving elevation and disintegrating degradation are generally simultaneous proceedings ; but from facts observed it seems more reasonable to infer that great glaciations were mainly local, except as arctic currents came down upon Central Europe freighted with ice.

Dr. Hector's statements lately made before the Geological Society in London, have a bearing upon several points of this discourse. The South Island of New Zealand has its Southern Alps of which Mount Cook, fourteen thousand feet high, is the highest, with a snow-field of one hundred and sixty square miles, in south latitude, nearly 44°. Judging by the moraine matter, snow formerly was vastly more abundant. He "demonstrated the excessive action of glaciers in cutting back cols; an action more energetic formerly; some of the cols having been worn down as low as eighteen hundred feet." "The reason for this contraction of the ice area is the great question for determination. Was it due to difference of climate, the result of a great glacial period? The remains of a past fauna afford no evidence of this. We may, indeed, suppose that the whole fauna migrated to the north; but we must, in that case *invent* the land and bring into play oscillations more extensive than those required for another alternative, viz:—the alteration of level, within the area itself. We might suppose a general alteration of level, even to the extent of four thousand feet higher than the present, but the evidence afforded by the shore line is unfavorable to this view. There remains the theory of *unequal elevation*, which combined with a most enormous destruction, the result of ages of glacier action, best explains the phenomenon." "In conclusion, the author stated his belief that there has been no general change of climate, but many changes of *relative level*, resulting in a great destruction of surface, which had taken place in groups of peaks at *different times*." Nature, January 27th 1876, p.

259. This statement is refreshing for its moderation and good sense. The isolation circumscribed the phenomena and forbade extraneous speculations.

Yet it is believed, that if we do look into general causes, and consider them well, we shall find that the forces of nature are so well balanced, that the imagined continental polar-ice sheet must be regarded as an impossibility; shall find that we need not raise mountains at the poles, against the effect of the force of the Earth's rotation, to slide down the ice; nor to submerge mountains and continents once elevated from the sea, again and again, to account for marine remains, or ice scratches upon the rocks, left there as they first emerged from the waters.

The theory of a north polar ice cap, spreading as a garment to the tropics, or to the fortieth degree of latitude only, seems not to have sufficiently considered the nature of the Arctic ice and climate. I open Dr. Kane's second Grinnell Expedition, and find that it wintered in Smith's Straits, latitude $78\frac{1}{2}^{\circ}$. In January the thermometer ranged from 64° to 75° below zero, Vol. 1, p. 154; from March 10th to 14th, the average was $46\frac{1}{2}^{\circ}$ below zero. "The intense cold approximates all ice to granite." Vol. I, p. 184. Look at the pictures; the ice is as hard and sharp of outline as unworn rocks. p. 162. The glacier that has shed its iceberg presents a vertical front; The ice-belt between the "floe" and the land, is "24 feet in thickness, 65 in mean width; the second, or appended ice 38 feet wide; and the third 34 feet. All three are ridges of immense ice-tables, serried like the granite blocks of a rampart, and investing the rocks with a triple circumvallation." *Ib.* p. 162.

Dr. Newberry, 2 Ohio Rep. 70, cites Dr. Kane's account of a sheet of ice, eight feet thick, resting on supports twenty feet apart, as having swagged five feet midway of the supports, while the weather was far below freezing point, to prove that the polar ice-sheet could flow southward. To one not wedded to that glacial theory the evidence does not seem so strong. With the weight of its own bulk on the centre of a span of twenty feet, we might believe there was a perpendicular pressure much more than proportionable to the force that propels the Alpine glacier. Yet in several months the strain caused no fracture of the ice; no fluxion of particles to change its form; but all except the bend remained of the same shape, and sharp of outline. If it had rested on a plane of the inclination of the bed of the Alpine glacier, there is no indication that its mass or particles would have moved a hair's breadth. It will here not be forgotten that a polar ice-sheet to be thousands of feet thick in New England must be of growing thickness all the way to the pole, and that the intensity* of cold for all that distance must have been greater than any Arctic cold known to us, and have held the ice formed in the water as firm as granite, and impervious to any heat that could reach it.

As to the snow that should fall upon land at a period of intense and long continued cold as supposed, it would not form into ice, or make the theoretical continental glacier. To make the ice of the moving glacier, there must be a back pressure from a greater elevation, and an *alternation of heat*

and cold; a thawing and regelation; so that climate may be too cold to make glaciers. Thus in Upper Thibet, on the north side of the Himalayas, the mean limit of perpetual snow is not only higher by more than a thousand feet than on the south side, but the belt of snow is narrower, the back pressure is less, and the snow deposited from the dry winds of Northern and Middle Asia are so dry as to make it questionable whether there are any proper glaciers, or anything more than the *nécé*, or dry masses of snow in layers. Reclus, 165-6; Professor Vogel, in *Nature*, March 16th, 1876, p. 394. Yet the snow there is seventeen thousand to nineteen thousand feet high, with a northern aspect.

Tyndall shews that ice is not viscous; will not stretch, but is brittle and will break under a strain, as when the glacier is compressed into a narrower channel; or must make a descent or curve; when the continuity is kept up by a back pressure and regelation; freezing then becoming an agency in wedging forward the mass in its shearing and descent. (*Hours of Exercise on the Alps*, 356, &c.) Yet under pressure it conforms to the valley and descends as if it were plastic. *Ib.* 358, 359, 401. To consider the difference between Tyndall and James D. Forbes, who held the theory of viscosity, is not now material. They both were dealing with the glacier in its cradle on the side of the Alps, having an inclination of four to five degrees, with a heavy incumbent pressure of the higher glacier, having a length of twenty or thirty miles, a width from two or three miles where widest; in one instance contracting from two thousand to 900 yards, with a depth sometimes of six hundred feet. Yet the downward flow was so slow as to require nice instrumental means to detect it, and though variable, owing to the difference of inclination, or choking of gorges, the figures for the day of twenty-four hours, most usually found are from twelve to twenty inches. 1 Lyell, 365, 366, 367. The flow is slower in winter than summer, and faster at the centre than the sides, and at the top than at the bottom.

It is apparent that the circumstances are not parallel with the supposed ice-cap at the North Pole. The existing testimony is, that this is an open sea; and if not that, is an ice covered sea, without land. There is not even level lowland for the ice to form upon. There is no mountain to bring the force of gravitation into operation. The ice that could saddle the pole could have no tendency to move in any direction, for there is no inclined plane. The hard frozen ice would not be borne downward by the weight of higher ice; nor crevices be filled by regelation, thus to wedge forward the frozen mass, as in high mountain regions. Greenland is a ridge of three thousand to four thousand feet elevation, and that will make glaciers in the valleys. But the supply of ice thence, or from Grinnell Land, or Labrador, to reach Europe, must have been *floating* masses; and so as to the interior of our country, if they came so far.

Ice is, in another respect, less likely to descend by land to a lower latitude from the pole, than if resting on a solid plane. Though the ice at a very low temperature would not melt in the air, yet, *resting on the water* it would become *sodden*, rot and sink; and without land support could not

rise to a height to spread the mass outward by its *own* fluidity, or any pressure of impending weight of ice. The point of least resistance would be the sodden ice and water beneath. The fresh ice contains no salt; the "water sodden," is "thoroughly infiltrated with salt-water." 1st Kane's Grinnell Expedition, 96. Captain Richard Wells, commanding the whale Ship Arctic, wrote to Mr. Grinnell, June 18, 1867, that he had steamed up Smith's Sound to about 79° of latitude; found the ice "rotten and very much decayed, the ship steaming easily through rotten floes. The ice on the east side, excepting in Whale Sound, appeared to have decayed away and parted from the land as far as the glass would carry, and would offer no impediment to the progress of any steam whaler. A poor foundation this, upon which to build a mountain of ice.

And consider also the geography of the Arctic region as to the proportion of sea and land, and the interposing elevations of the land. Remember, also, that the earth's features at the supposed glacial period were in outline the same as now. A polar ice-sheet to cover North America and Northern Europe must have filled the ocean to the bottom and risen to a height far above the sea to compel the ice to move by pressure southward to the 39th or 40th degree. We need not estimate what that height must be, when we know it would have no land basis to rest upon; and know also that intermediate mountains, indeed all land, would be obstructive of progress instead of sources of power. In Europe, such a polar ice-sheet must have filled the Arctic Sea, and risen from its bottom over the mountains of Norway, Sweden and Scotland. In North America it must have risen over the mountains of Grinnell Land, that of Greenland, and the Labrador and Laurentian ranges, and crossed the St. Lawrence River. But glaciers under pressure would sooner squeeze through a gorge, as two thousand yards in width will pass through a defile of nine hundred yards in the Alps. The channel of the Atlantic would be preferred to the elevated land to travel southward across fifty degrees of latitude by land. The continental ice-sheet would have been a glacier in the Atlantic. That the north polar sea is open, is not only proved by men who have looked upon it, but Dr. Scorsby testified that the "Right Whale" that always shuns the tropics, has carried the marked harpoon from Baffin's Bay, through Behring's Strait, into the Pacific; and the whale must breathe the air. He could not cross the equator, nor go under ice into the Pacific, Maury's Ph. Geog. of the Sea, Sec. 144. The birds go to the north of Greenland to breed because there they find their food in an open sea; and we know that northwest of this continent the Arctic Ocean extends down to the seventieth degree of latitude.

Again: Concede the extreme glacialists solid land at the pole for the ice-cap to rest upon; yet consider the enormous demand made upon our credulity to meet the conditions of their theory. The ice-sheet is to be from ten to fifteen thousand feet thick in New Hampshire, according to Agassiz: It is to reach the fortieth degree of north latitude according to several other glacialists. To give it the pressure by gravitation of the glaciers

of the Alps it must rest upon an inclined plane of four and a half degrees descent; or have such an elevation at the pole in its own thickness as to be equivalent to that inclination; and that would require a height of ice at the pole of two hundred and seventy-one miles, that the sheet might reach the fortieth degree of latitude. The statement of such requisition seems sufficiently condemnatory of the theory.

There are laws of limitations ever ruling all nature, including the powers of the air. These all have their boundaries they may not pass; their effects cannot transcend their limited cause. When we consider and perceive that no glacier or polar ice-sheet can be formed without snow, we must also perceive that the quantity of snow must find a limit in the heat that evaporates the water into the air that shall fall as snow. Create the Arctic climate over the world, that is requisite to maintain the supposed great ice-sheet unmelted, and you cut off the amount of evaporation necessary to form and preserve that ice-sheet. You have thereby made it an impossibility. To diminish the Sun's heat is to cut off the supply of snow to build the great glacier. Tyndall on Heat, 206. "We cannot afford to lose an iota of solar action; we need, if anything more vapour; but we need a condenser so powerful that this vapour, instead of falling in liquid showers to the earth, shall be so far reduced in temperature as to fall in snow." Ib. 207. That condenser must be *the mountains*, or be the polar cold. But the supply of *heat* from the Sun is ever a *constant quantity*. "This expenditure, (of the Sun) has been going on for ages, without our being able, in historic times, to detect the loss." Ib. 434. It is a supply ever dispensed; never spent, never varied; and will not permit the growth of the great ice-sheet. Less heat would make less snow, and snow must make the ice-sheet or glacier.

The theory supposes the ice-sheet to reach below the 40th degree of latitude; and the cold influences of that would extend over the world. There would not only be a failure of evaporation to fall as snow to maintain the ice-sheet; but the snow formed *could never reach the pole*, or approximate it, to form the head and pressure to drive southward the continental glacier. The evaporated moisture of the tropics would be precipitated in snow as soon as chilled at the freezing point first reached; that is, as soon, at least, as it reached the ice-sheet. We find such to be the law of snow precipitation on the highest mountains. "According to Tschudi the quantity of snow which falls upon that portion of the Alps which is above 10,800 feet is comparatively very small. Most of the clouds charged with snow flakes discharge their burden on the mountain slopes at elevations of 7,000 to 8,000 feet." *The Earth*; by Elisée Reclus, 163. Mountains in Thibet 20,000 feet in height are therefore found denuded of every particle of snow, because the dry winds there have not the moisture to dispense in snow; and for the same reason the north side of the Himalayas have the lower snow line higher than that on their south side, where the heat is greater and the moisture more abundant. Ib. 165-6. Hence also there is an *upper*, as well as a lower snow line on very high mountains. Speaking of

Mer de Glace and the Mer d'Aletsch, Reclus says, "It is a very remarkable fact, in regard to both these glaciers, and those of the Himalaya, that the ice-rivers are much longer and more abundant on the southern side of the mountain than on the colder slopes which are turned to the north. This phenomenon must evidently be attributed to the larger quantity of snow brought by the south wind, and impeded in its course by the lofty mountains." *Ib.* 211-2. Thus the most snow comes from the side where there is the greatest heat for evaporation.

Dr. Hector shows that the same phenomenon takes place in New Zealand as in the Himalaya and other mountains; namely that the snow fall is greatest to the windward, whenever the temperature is at freezing point: "Much of this enormous precipitation is deposited as snow in the Southern Alps, which *comb* out the moisture from the westerly winds; hence the extensive glaciers of the mountain region and the comparative dryness of the Canterbury Plains." *Nature*, Jan. 27, 1876, p. 259.

As the climate of the world now is, the greatest quantity of snow does not approximate the pole, though it will last longest there. It is more abundant below than above the fiftieth degree of latitude. In British America, above that degree six days of snow in a winter, and a depth of three and a half feet, are normal quantities. *9 New Am. Cy.*, 327. With an ice sheet down to 40 degrees of latitude the deepest snow would probably be midway between the equator and pole.

There is, therefore, no cause of the continental polar ice-sheet found in the air; nor is there any effect of it seen under the earth, where the effects should have been often seen, if it proceeded from a planetary cause, for then it should have been of periodical occurrence, and the effect have been seen in fossils in the rocks. Since land first peered above the waters to yield disintegrated material for the deposit of the sedimentary strata, the rocks have kept the registry of every species of plant and animal, and thus recorded the temperature of the globe, and told us that the time was when tropical plants grew on the shores of Greenland. There, on the east coast are the Carboniferous slates and coal, and on the west side of the Island of Disco, at latitude over 69°, are impressions of the rankly growing vegetation of the tropics. The succession of stratified rocks, as arranged by Lyell in his table in their order of deposition, number thirty-eight, 1 vol. 135, commencing at some period of that long "beginning," when the earth was first in preparation for man's inhabitancy. No stratum of all those rocks tells of an ancient glacial period, while they all proclaim that the Earth was a constantly cooling sphere, that it might become fitted for the home of human beings. This process of cooling must have followed that uniformly diminishing rate with which a hotter body radiates its heat into space, with the local exceptions made by mountain elevations, the distances of the poles from the Sun's direct rays and by ice-bearing ocean currents. And certainly the Sun has in no period of the past dispensed less heat to the Earth than now. If there be any fact on, or within the Earth, or without it, to prove the contrary of such inductions from normal causes, it

is to be shown, not conjectured, not invented. We are not to be permitted to explain a difficulty by an imagined cause that involves tenfold greater difficulties. This they seem to do who make the induction of a continental polar ice-sheet, such as the glacialists describe it, with the vividness of those who might have seen it. Though their subject be glacial they write with a fervor that betrays an enkindled imagination.

James Croll emphatically invokes an astronomical cause for the Glacial Epochs; but the astronomers have expressed adverse opinions. Humboldt. (4 Cosmos 460) thus quotes Poisson on the Stability of the Planetary system: "It follows from the theorem of Lambert, that the quantity of heat which is conveyed by the Sun to the Earth is the same during the passage from the vernal to the autumnal equinox as in returning from the latter to the former: The much longer time which the Sun takes in the first part of its course, is exactly compensated by its proportionately greater distance, and the quantities of heat which it conveys to the Earth are the same while in the one hemisphere or the other, north or south." Humboldt also quotes Arago on Excentricity: "As the excentricity always has been, and always will be, very small, the influence of the secular variations of the quantity of solar heat received by the Earth upon the mean temperature would appear also to be very limited." If these opinions be true we must look to earthly causes; and not to the Earth's orbital excentricity produced by conjunction of planets in the heavens, or variable heats from the Sun.

There is, however, one cause besides the elevation of the mountains, and the inter-continental influx of the Arctic Sea, whereby the temperature of Northwestern Europe, may at sometime, have been greatly reduced, and that without any cause at variance with the normal physical laws. We have shewn many proofs why there was a central ocean between the widely spreading systems of mountains of the Eastern and Western parts of North America. It may hence have been that the waters heaped up by the Earth's rotary motion, and the trade winds into the Gulf of Mexico, found a passage through that inter-continental sea; and were not, as now, compelled to find their exit by Cape Florida and the Atlantic Ocean, to reach and warm Western Europe. Dr. Dawson did not suggest such a cause for such effect; but said what would truly be the consequence of such cause when he said, "any change that would allow the equatorial current to pursue its course through to the Pacific, or along the great inland valley of North America, would reduce the British seas to a boreal condition." Dawson, 79. The fact shown, the induction is legitimate and inevitable; and seems to be proved by established isothermal lines, shewing how greatly the gulf-stream mitigates climate.

How then are we to account for a past period of glaciation, of whatever intensity, greater than at the present time in certain places. We may do it without invoking abnormal causes. An adequate cause exists within less than five miles of every foot of the surface of the earth. Within that limit, with land elevation to the height of the upper snow line, and breadth to hold an adequate *Mer de Glace*, yet with a sufficient declivity to put the

ice in motion by gravitation, we have all the conditions necessary to account for all the glaciation and glaciers of which we find the traces in every country. That the greater glaciers have had such cause seems apparent from their effects remaining where the glacier ice left them. Within reach is ever the producing mountain, or was the open sea to the Arctic. These are sufficing causes for all we see within the range of the causes. The grooves of greater glaciers are seen in parallel lines at great heights on the mountain sides of the glacier-valleys, where glaciers now are, and in thousands of places where they have ceased to be; and there are the *moraines*, and the rocks *moutonné*, rounded and scored rocks in place, and those transported, all having an exact relation to the moving cause. The Earth by Reclus, Ch. 36. These are the certain proofs that the mountains have been greater, and the evaporation not less, but probably much greater, when the Earth was warmer. For these a continental or polar ice-sheet would in no wise account. It is not needed and is an unfitting explanation of the boulders spread so widely south and east of the Baltic, and even over Scotland, Wales and England; and such degree of cold may have been so induced by mountain elevations and Arctic sea currents as to invite Arctic animals and plants southward and to drive other animals further south. "It is now beyond all question," says Reclus that the numerous lines of rocks which are found here and there all over Northern Russia have proceeded from the granite mountains of Scandinavia. When an immense sea extended over Finland between the Baltic and the Polar Ocean, the blocks of ice which fell into the water that washed the base of the Scandinavian mountains, drifted away in flotillas towards the southeast to the shores of the continent opposite. The prominent angles of the granite blocks contained in the masses of floating ice have traced out long furrows over all the points and projections of the rocks in Finland, which was then only a marine shoal. M. Nordenskiöld has ascertained that almost all these lines of erosion tend from the northwest to the southeast, and that all the rocks with which the icebergs have come into contact are polished on the side which faces toward Scandinavia, while on the other side they have in every case retained their uneven surfaces, their projections and their clefts. With regard to the boulders themselves, they are all more rounded by friction the more distant they are from the Swedish mountains of which they once formed a part." *Ib.* 219. And the same effects are there yet taking place, on a smaller scale.

During the winter of 1862-3, immense masses of ice, coming from Finland, were cast upon the southern coast of the gulf, and thrown upon the land a distance of more than three hundred yards from the shore, and to a height of thirty feet above the level of the sea. The ice which was forty to fifty feet deep, overwhelmed many dwellings and whole forests. In the latter large quantities of stones were subsequently found, which the ice left when it thawed. Reclus, 219, citing Keyserling and Von Baer.

The Danish Professor, Dr. Forchhammer, relates a striking fact to show that large quantities of rocky fragments are annually carried by ice out of

the Baltic. In the year 1807 he says, at the time of the bombardment of the British fleet, an English sloop of war, riding at anchor in the roads, at Copenhagen, blew up. In 1844, a trustworthy diver found the space between decks entire, but covered with blocks from six to eight cubic feet in size, some heaped on others; and he found all the sunk ships he visited thus loaded with rocks. 1 Lyell, 382. Now when the Baltic sea was opened to the north pole, and when much of Europe south of the Baltic was below the water level, there was the same condition there as has been shown to have been in North America; namely, an open sea to bear down ice-rafts from the north to supply the drift and boulders that are found spread over both countries, bringing with them a cold atmosphere.

The most recent account of the drift on the eastern side of North Wales, by D. C. Davies, F. G. S., gives us his conclusions: "1. The majority of the deposits are of local origin, being derived from the mountainous regions of North Wales, then an Archipelago of islands. 2. But from the plentiful admixture of foreign matter, he infers *an open sea* on the north. 3. He insists upon the necessity of *aqueous conditions*; the coast would be partly ice-bound, but *there was no general ice-cap*. Besides the general alterations of level there were *local alterations of level*. Proofs of this were to be seen in the neighborhood of Oswestry, beyond which town the Scotch granites do not seem to pass. This the author considered due *to currents* deflecting the *ice-rafts*, &c. Nature, Feb. 17, 1876, p. 318.

Let us be reassured, then, of the safety of Europe and North America, and the world. The Creator, we may believe, did not create the best parts of this Earth and plant there the highest civilizations ever seen upon it, with purpose of its utter destruction. These countries in Europe and America are the hopes of the race, with means of execution, now presented, as they have never been before. There is a uniformity of law, and stability in Nature, that justify man's confidence in the ruling of The Supreme Power, and that He is good. They who most profoundly study His works are the most thoroughly convinced that there is no eccentricity or caprice in His Rule; that He is "The same yesterday, and to-day, and forever." The oscillations of the Earth have become almost infinitesimal; the vertical vibrations as measured by the temple of Jupiter Serapis have not exceeded thirty feet; many volcanoes have been sealed up and people live securely within the rim of former craters; the Valley of the Mississippi will never again be an ocean's bed; the Gulf Stream will continue to mitigate the climate of Europe and preserve its genial temperature; and the Earth continue to turn upon its axis, and to revolve in its orbit, without a tremor; without a moment's loss or gain. God's balance wheel belts this Earth; and He gave to our globe those impulsions in its rotation and orbit which will forever precisely counteract its weight, and maintain its motions with such exactness as will keep all true time forever. Such momentum was given once forever. If not so, then God is forever sustaining His creation.

This earth has never, and upon the certain evidence of Geology, will never suffer a cataclysm. The faults of strata are limited and local; the

surface is fashioned by exterior agencies that level, smooth and beautify the world, and fit it for man's use and enjoyment, but which can never mar the sublimity of the cataract, or the majesty of the mountains; many of these crowned with never wasted snows. Some volcanoes yet burn to relieve the earth of the throes of its internal heat and gases, and to tame the earthquakes; yet are the latter sufficing agencies needed to raise the mountains commensurately with the degradations of the disintegrations and erosions of prevailing frosts, heats and rains. None of these, however disturb the general movements of the earth in its orbit, or on its axis, by the slightest vibration, or cause the delay of a second in time in its annual revolution. The Supreme Ruler has taken into the account every cause, and provided against disturbance, in advance; or at every moment keeps all things adjusted to absolute truthfulness. The cooling and shrinkage of the earth's crust, would upon mechanical principle, shorten the radius of the earth's axis, and hasten its rotation, and shorten the day; but as Humbolt says, this is provided against by the celestial movements being adapted to the thermal condition of our planet; and "from the comparison of the secular inequalities of the Moon with the eclipses observed in ancient times, it follows that since the time of Hipparchus, that is, for two thousand years, the length of the day has certainly not diminished by the hundredth part of a second. The decrease of the mean heat of the globe during a period of two thousand years, has not, therefore, taking the extremest limits, diminished as much as $\frac{1}{368}$ of a degree of Fahrenheit." 4 Humboldt's Cosmos, 168.

Some scientific men, and some that may not be truly such, seem fond of writing sensationally, to disparage the creation and to alarm mankind as to the stability and permanence of our planetary home. Andrew Wilson, in giving his travels in "The Abode of Snow," or Himalaya, in the first page of his preface suggests that it is not "an improbable theory that when the accumulation of ice round the south pole has reached a certain point, the balance of the earth must be suddenly destroyed, and this orb shall almost instantaneously turn transversely to its axis, moving the great oceans, and so producing one of those *cyclical catastrophies*, which there is *some reason to believe* have before now interfered with the development and civilization of the human race." One supposes, of course, the traveler to be playfully jocose when he thus speaks to recommend his favorite Himalaya as a safe place of retreat; the Himmels or heavens of our Aryan ancestors; yet Professor Winchell in a work of science is even more sensational, and has several serious chapters upon the inevitable progress of Creation to its ruin; in chapters headed "The Reign of Universal Winter," "The Sun Cooling off," "The Machinery of the Heavens Running Down;" and quotes Helmholtz as saying, "The inexorable laws of mechanics shew that the store of heat in the sun must be finally exhausted." And thus the author of the article "Force," in Chamber's Encyclopedia, gives his views of the finality: "This, then, it appears, is to be the last scene of the great mystery of the universe, chaos and darkness, as 'in the beginning.'"

Either then, the universe has been subjected to laws to make waste and decay impossible, and all things that undergo change are preserved in quantity and energy to preserve the whole forever in balance; or there is a Power that ever renews them; for we see that creation does not wax old, but that equal quantities of matter and force remain ever operative without detection of a moment's pause through thousands of years; without the loss of an atom of matter, of force, of heat, or light, without a discord, or tremor in the harmony of the Universe.

Adhering strictly to the Baconian canon of philosophy, to which all philosophers must be held; that is, to proceed only on well ascertained facts, and thence making inductions only in accordance with the laws of nature, also ascertained as facts, it is submitted that it will not be found that creation is ever growing weaker, is not verging to decay and annihilation. The more we shall know, the more profoundly we shall consider, the more surely shall we be reassured that this earth is not to perish by ice, or water, or fire; that the force that holds the systems of suns and planets in their rotary movements will never abate: that suns will not burn to cinders, nor their heat and light be spent or extinguished. And by the observance of the same canon of philosophy, of certain ascertainment of facts and strictness of induction, we must also infer from all creation, and creation's laws, that it had an Author to give it law, who wills to conserve it for ever; Him of whom we truthfully say, "Thy law is the Truth:" By, "Thy faithfulness shalt Thou establish the very heavens."